Vacuum-Cooling Lettuce

in Commercial Plants

U. S. DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service
Market Quality Research Division

AMS-469

CONTENTS

ACKNOWLEDGMENTS

The Grower-Shipper Vegetable Association, Salinas, Calif., and the Western Growers Association, Los Angeles, Calif., contributed lettuce and other aid, and arranged for the use of various vacuum-cooling facilities in this study.

W. J. Lipton, U.S. Horticultural Field Station, Fresno, Calif., conducted tests on the keeping quality of the lettuce.

J. K. Stewart, U. S. Horticultural Field Station, Fresno, and Roy Hanna, Field Department, Western Growers Association, assisted in obtaining the cooling data.

This report supersedes "Rapid Vacuum-Cooling of Lettuce," AMS-469 (Preliminary Summary), issued March 1962.

Washington, D.C. July 1962

VACUUM-COOLING LETTUCE IN COMMERCIAL PLANTS

By W. R. Barger, senior horticulturist,
Horticultural Crops Branch, Market Quality Research Division
Agricultural Marketing Service

SUMMARY

Tests at commercial plants showed that carton-packed lettuce could be vacuum-cooled to a final tank pressure of 3.8 millimeters of mercury (3.8 mm. Hg.) without danger of freezing. Previously, a pressure of 4.6 mm. Hg. had been considered low enough for efficient cooling. Exhaustion of the air to the lower pressure of 3.8 mm. Hg. brought the lettuce down to an average temperature of 34 degrees F. in about 15 minutes, compared with cooling to that level in 23 minutes under the higher pressure.

The saving in time is particularly advantageous during the height of the harvest season when large quantities of lettuce must be precooled. There is a tendency during this period to sacrifice some cooling in the interest of moving more volume through the chambers. The improved techniques also resulted in more thorough cooling, with resultant improved market quality and reduced wastage.

Pressure gages more sensitive than those ordinarily used were required to provide accurate knowledge of the minimum pressure within the cooling tank during the final period of each run. The cost of such equipment was low in comparison with the advantages gained from its use. Ordinary wet-bulb and pulp thermometers were not reliable as guides for controlling tank pressures in the low ranges necessary for best cooling results.

Control of condenser temperatures in mechanical plants also was necessary for the most efficient cooling. The ammonia gage on the refrigeration line was not a true indicator of actual coil temperatures. Operators should use thermocouples to measure surface temperatures at the inlet and outlet of the condenser. A minimum average coil temperature of 29° F. was safe and contributed to the fastest cooling.

BACKGROUND

The major objectives in vacuum-cooling lettuce commercially are (1) to cool the heads sufficiently to preserve the initial quality of the lettuce and (2) to hold to a minimum the time required to reach the desired temperature.

Studies with the pilot vacuum-cooling plant at the U.S. Horticultural Field Station, Fresno, Calif., showed the effects of minimum pressures and other factors on the rate of cooling lettuce.[1] The results indicated (1) that the lower the pressure the faster the cooling, (2) that the butts of head lettuce cooled much more slowly than either the leaves or the wet-bulb thermometer used for controlling the vacuum cycle, (3) that continued holding under low pressure after the wet-bulb had reached 32° F. was necessary to cool the entire head properly, (4) that controlling the condenser temperature at a 29° minimum was necessary to avoid danger of freezing the leaves, and (5) that the sooner the "flash," the shorter the cooling time, other conditions being equal. The flash occurred when the tank pressure first became low enough to cause a substantial release of moisture from the lettuce and the start of cooling. It was indicated by a sharp rise in the temperature of a wet-bulb thermometer suspended in the tank.

[1] Barger, W. R. Factors Affecting Temperature Reduction and Weight Loss in Vacuum-Cooled Lettuce. U.S. Dept. of Agr., Mktg. Res. Rpt. 469, 20 p. Apr. 1961.

Since conditions in the pilot plant may vary from those in larger installations, tests were run in three commercial plants to determine the relation of these findings to the cooling of large lots of carton-packed lettuce. This study is a part of a broad program of research to maintain quality and reduce waste in the marketing of fresh vegetables.

VACUUM-COOLING PLANTS STUDIED

The vacuum-cooling facilities studied included: (1) A half-car tank with mechanical vacuum pumps and refrigerated condensers, (2) a half-car tank with steam jets and barometric condensers, and (3) a "unit cooler" utilizing mechanical vacuum pumps and refrigerated condensers.

The half-car tanks were approximately 6 feet in diameter and 50 feet long, and held 12 pallets, each carrying 30 cartons of lettuce. The unit cooler was large enough to hold a loaded refrigerator car or truck trailer.

The condensers, used in the mechanically exhausted tanks, were bare iron cooling coils refrigerated by circulation of liquid ammonia.

TEST EQUIPMENT AND DATA

A sensitive high-vacuum gage (dial-type) was installed to measure, in millimeters of mercury (mm. Hg.), the lower range of pressures in the tank. This gage was much more sensitive than the one supplied as standard equipment. Small thermocouples were used to measure wet-bulb temperatures in the tank atmosphere and the temperatures in leafy and butt portions of heads in four cartons during each run. Thermocouples also were used to measure the temperature of the condenser coils in mechanical plants for comparison with the theoretical temperature of the refrigerant as indicated by the gage on the ammonia line.

Temperatures were recorded at 20-second intervals. Ammonia and vacuum gages usually were read at 1-minute intervals. The time from the flash to breaking of the vacuum ranged from 14 to 25 minutes. Minimum pressures attained in different vacuum runs ranged from 3.6 to 4.6 mm. Hg.

In most instances, the cartons in which temperatures were taken were weighed before and after cooling, to determine moisture loss due to the vacuum treatment.

The average temperatures of the lettuce after cooling were determined by taking the final readings obtained in the leafy and fleshy (butt) portions of the heads and calculating a weighted average based on a proportion of 80 percent leaves and 20 percent butts. Laboratory studies showed that head lettuce contained approximately 80 percent thin leaves by weight and 20 percent midribs, butts, and other fleshy tissue. Temperatures of the midribs after vacuum-cooling were similar to those taken 1/2-inch deep in the butts. Consequently, the average temperature of an entire head, apportioned on weight of leaves and fleshy tissue, was approximately 34° F. when the leaves were 32° and the butts 40°.

CONTROLLING THE VACUUM CYCLE

In the usual commercial operation, the vacuum-cooling cycle was controlled by reference to electric resistance thermometers or thermocouples measuring wet-bulb temperatures in the tank air or pulp temperatures of lettuce in a carton. Some tanks were equipped with thermometers for both wet-bulb and lettuce temperatures, to aid the operator in obtaining the desired rate and degree of cooling.

Since vacuum-cooling depends entirely upon the vapor pressures obtained in the tank, the interrelation of these thermometer and gage readings to the tank pressure was studied as a guide to the most effective use of the vacuum equipment.

Pressure reduction and the resultant cooling were regulated, in steam plants, by the number of high-vacuum jets or boosters used during the vacuum run. Pressure regulation in mechanical plants was accomplished largely by varying the vapor load in the tank by turning the refrigeration on or off in the condensers.

Wet-bulb and pulp temperatures not sufficient.--Wet-bulb temperatures from the flash until the pressure became low enough to freeze the wick nearly coincided with the temperatures of saturated water vapor (boiling points) at the various tank pressures (fig. 1). However, when the wick froze, the temperature of the wet-bulb remained at 32° F. too long to reflect accurately any further reduction in pressure.

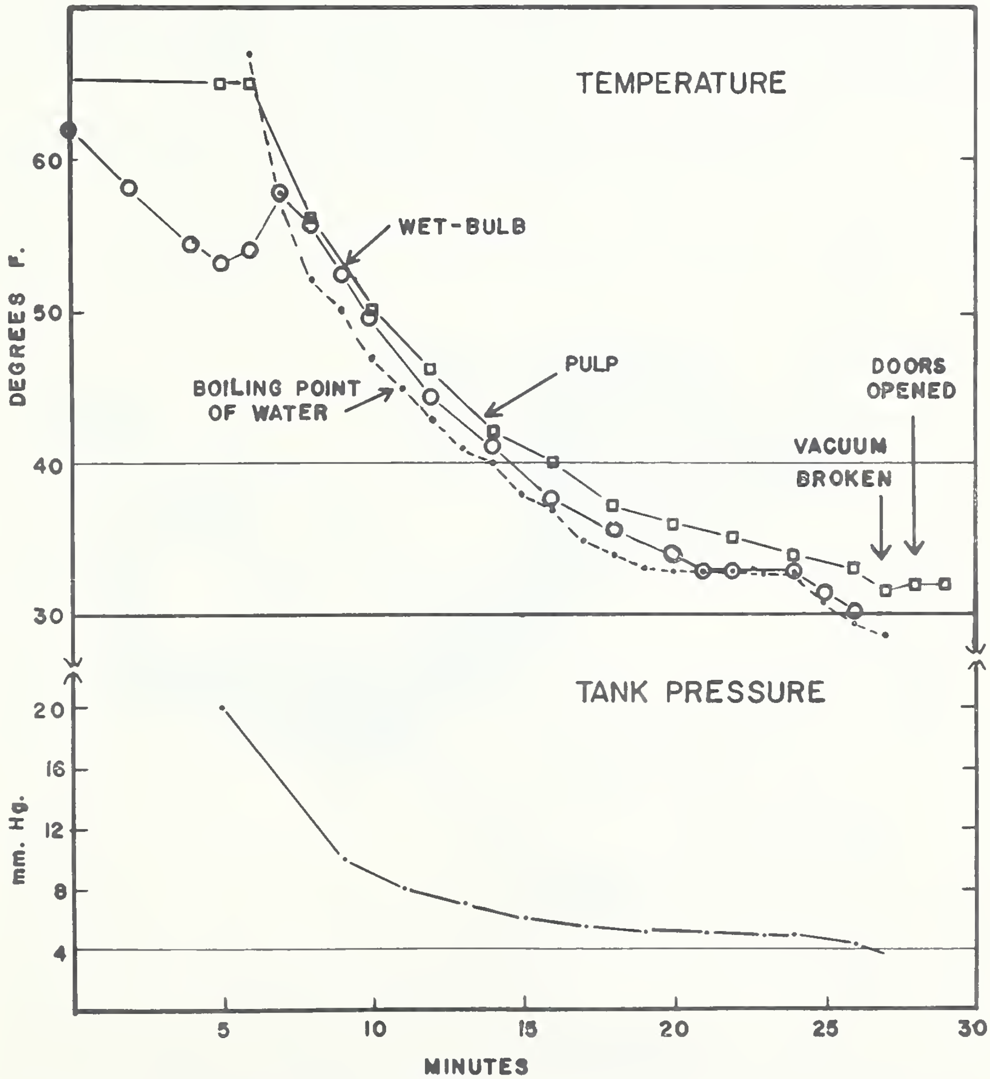

Figure 1.--Relation of wet-bulb and pulp thermometer readings to tank pressures during vacuum-cooling of lettuce.

Pulp temperatures of lettuce, measured by thermometers stuck into heads of lettuce in cartons, lagged behind the wet-bulb temperatures during the cooling period and did not reach 32° F. until several minutes after the wet-bulb froze (fig. 1). No cooling occurred before the flash.

Stopping the vacuum cycle as soon as the lettuce thermometer reached 32° F. gave no assurance that the entire head was cooled to this temperature (see fig. 3, p. 7).

The conditions that limited the use of wet-bulb and pulp thermometers for the control of vacuum-cooling did not affect the high-vacuum gage. With this gage as a guide, the pressure in the tank could be controlled precisely enough for thorough cooling of the lettuce without danger of freezing.

Ammonia gage readings misleading. --In mechanical plants, the vapor pressure in the vacuum tank is affected by the temperature of the condenser--the colder the condenser, the faster the drop in pressure. Thermocouples soldered to inlet and return pipes showed that the surface of the condenser was 26 to 49 degrees warmer at the flash than the temperature indicated by the ammonia gage (fig. 2). Later, when most of the heat

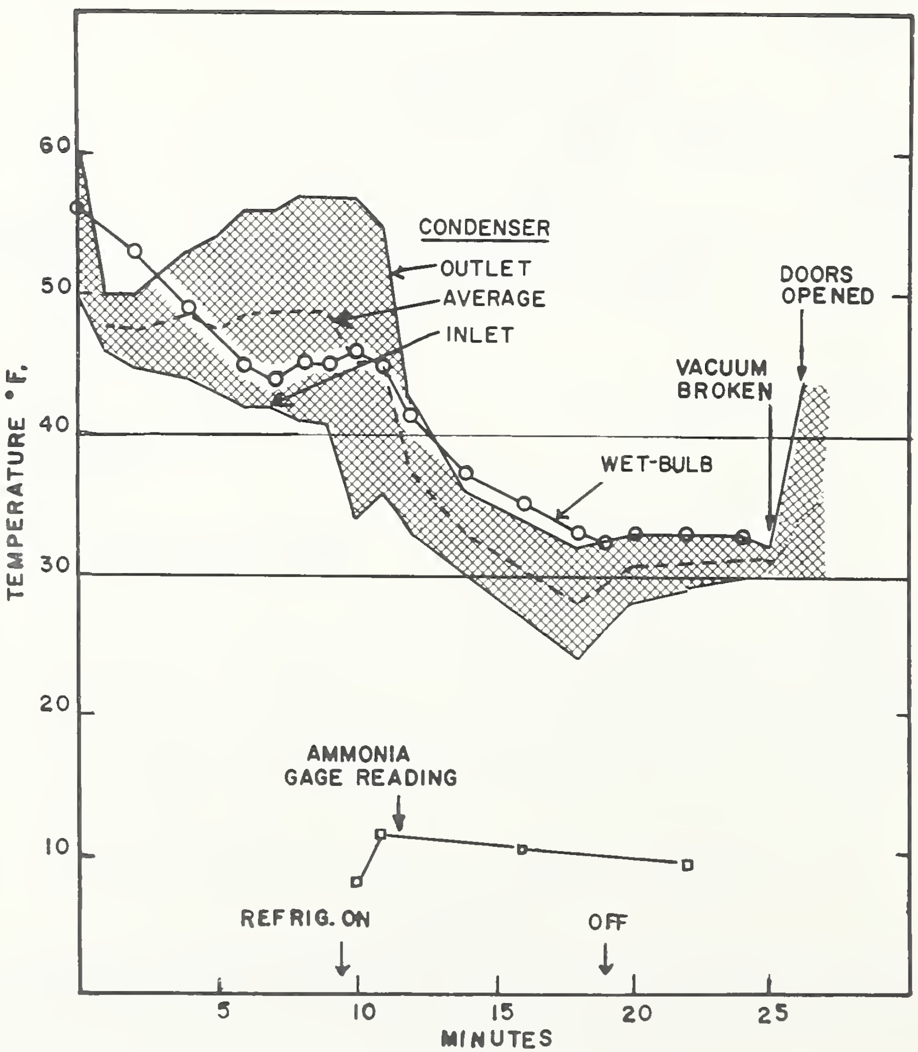

Figure 2. --Comparison of temperatures at surface of condenser to readings of ammonia gage during vacuum-cooling of lettuce.

was removed from the load, the difference was 14 to 22 degrees. During this vacuum run, the average temperature of the condenser was above 32° F. most of the time despite the subfreezing temperatures indicated by the gage. By the time the condenser had cooled to a 28° average, the refrigeration was turned off to stabilize the tank pressure. Continued operation of the condenser at this temperature would have frozen the lettuce[2]. There was no correlation between the temperature of the ammonia, as indicated by the gage, and the temperature of the condenser at the surface of the pipes.

In this condenser, the ammonia lines were about 25 feet long between inlet and return headers. Greater spreads between inlet and outlet temperatures were found in condensers with longer ammonia lines between headers.

COOLING STUDIES

Cooling to 34° F. desirable.--In laboratory tests, lettuce vacuum-cooled to 34° (weighted average of leaves and butts) and held 9 days at 34° had less decay and russet spotting than lots either vacuum-cooled to 38° and held at 38° or ice-packed and held under top ice. The benefits from vacuum-cooling to 34° and holding at this temperature were more pronounced after 3 days' additional holding at a retail display temperature of 50° than immediately following the 9-day simulated transit period.

Lettuce butts cool slowly.--Typical curves indicating the rate of cooling of leafy and fleshy portions of head lettuce during vacuum-cooling are shown in figure 3. They show

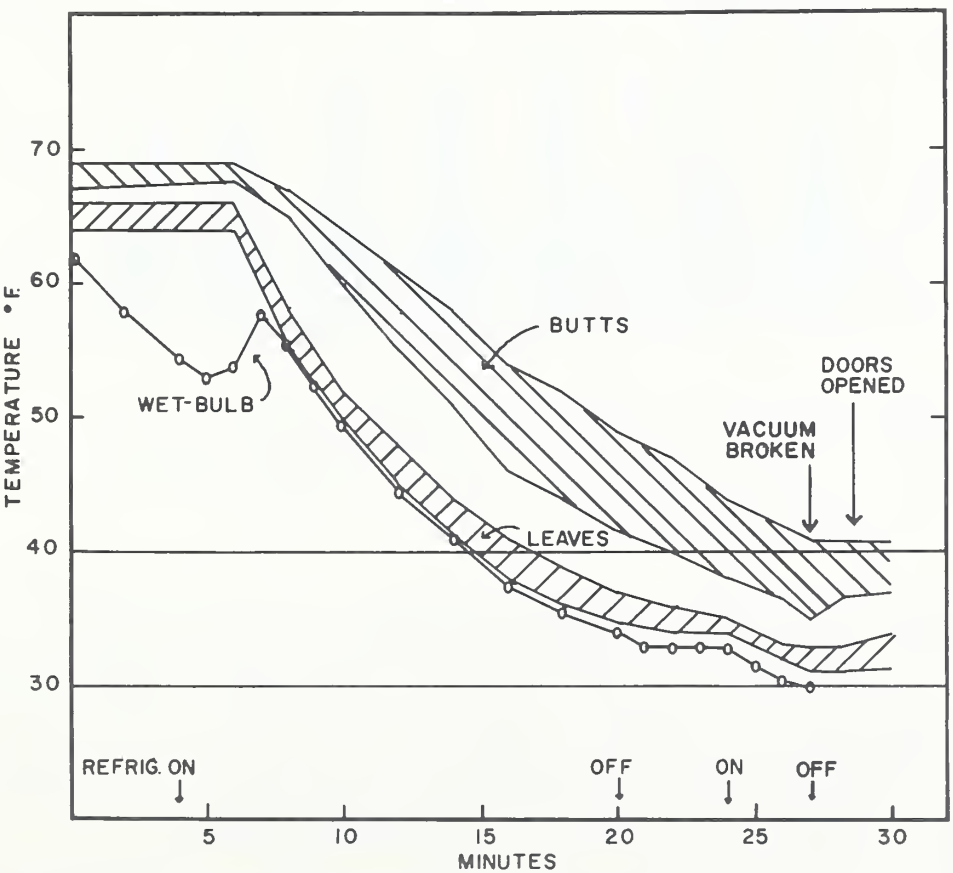

Figure 3.--Temperature spread and reduction in leaves and butts of lettuce in four cartons during vacuum-cooling.

[2] See footnote 1, page 3.

the range of temperature in four cartons at each reading. Leaf temperatures taken by thermocouples thrust into the center of the packed cartons started at 64° to 66° F. and dropped to 34° to 35° in 24 minutes. Final temperatures ranged from 31° to 34° after a vacuum cycle of 28 minutes. Leaf temperatures in some cartons were close to the wet-bulb temperatures for most of the vacuum cycle.

The butts cooled much slower than the leaves. Temperatures taken at 1/2-inch depth were 37° to 41° F. after a 28-minute vacuum cycle. The relatively slow cooling of the butts and the spread in butt temperatures in different cartons showed the need of a definite time under vacuum for thorough cooling of the entire head and load, regardless of the speed at which the leaves were cooled to 32°.

Time from flash important.--Lettuce temperatures after vacuum-cooling times of 14 to 25 minutes from the flash to a minimum pressure of 4.0 mm. Hg. are shown in figure 4.

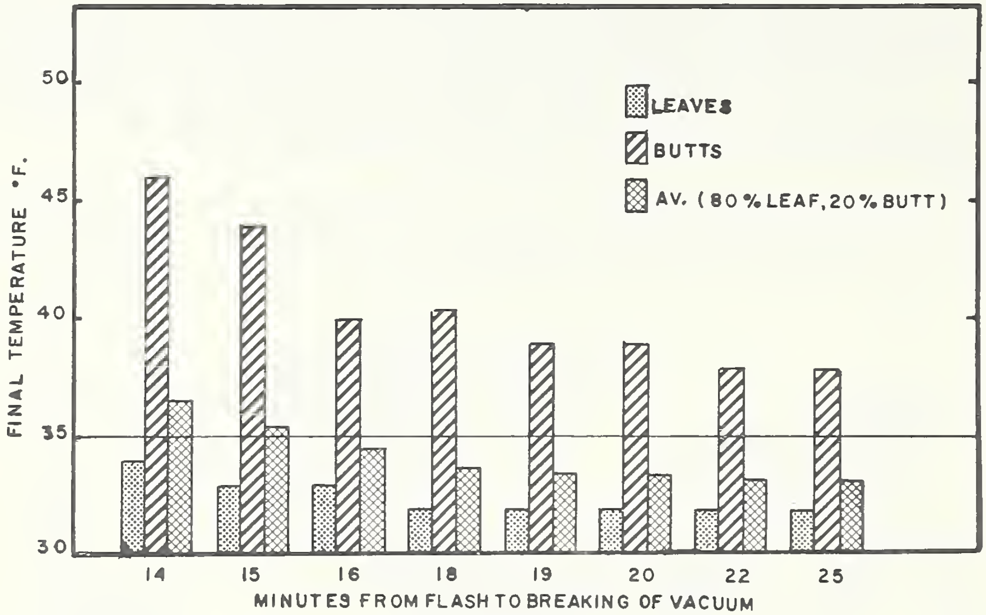

Figure 4.--Effect of time under vacuum after the "flash" on final temperature of lettuce, initially 68° to 72° F., vacuum-cooled to a minimum pressure of 4.0 mm. Hg.

Although the leaves were cooled from initial temperatures near 70° F. to final temperatures near 33° in 14 minutes from the flash, the butts required 16 to 18 minutes to reach 40°. Average temperatures of 34° or lower for the entire head were not obtained until the butts were cooled to at least 40°.

Cooling time shortened by lowering tank pressure.--Since the time required for each vacuum-cooling run was of economic importance, especially during peak periods at harvest, cooling times were compared for minimum pressures ranging from 3.6 to 4.6 mm. Hg. At a minimum pressure of 4.6 mm. Hg., usually considered adequate for vacuum-cooling lettuce, evacuation for 23 minutes after the flash was required to cool packed cartons to a 34° F. average; at 4.0 mm. Hg., it took 16 to 18 minutes; and at 3.8 mm. Hg. the time was reduced to 15 minutes. Evacuation to 3.6 mm. Hg. pressure resulted in lettuce temperatures averaging 32.2° (31° leaf, 37° butt) 18 minutes after the flash. Although no freezing of the lettuce was apparent after any of these runs, lowering the pressure below 3.8 mm. Hg. would involve some risk.

Positions in carton and on pallet affect final temperatures.--Some variations occurred in the temperature of the lettuce within individual cartons and between cartons in the load during vacuum-cooling, especially in the butts. Individual butt temperatures taken at the 1/2-inch depth ranged from 33° to 38° F. in 24 heads in a single carton after a good vacuum cycle. The range was 36° to 44° after a poorer run. Leaf temperatures

ranged from 31° to 34° in both instances. The best cooling occurred near the vents in the sides and bottom of a carton. Cooling was retarded in the unvented corners and also in the top layer when a paper shield was used under the closure.

When the cartons were stacked on pallets for vacuum-cooling, the average final temperatures of the lettuce butts were consistently lower in the top layer of the load than in cartons placed deeper in the pile. No consistent differences in temperature were found in cartons distributed lengthwise of the tank in the same layer and row in the load.

Lettuce vacuum-cooled in a unit cooler showed no consistent difference in final temperature lengthwise through a loaded refrigerator car. However, as with cartons on pallets, cooling was slightly faster in the top than in the middle- and bottom-layer cartons.

<u>Weight losses during vacuum cooling</u>.--Since vacuum-cooling depends on the evaporation of moisture from the plant tissue, the reduction in temperature should be reflected in the loss in initial weight.

Warm lettuce lost more weight than cooler lots. Average weight losses in cartons of lettuce weighing approximately 47 pounds and vacuum-cooled to 34° F. from various initial temperatures were:

Initial temperature	Weight loss		Temperature reduction
°F	Pounds	Percent	°F
74	1.7	3.6	40
65	1.4	3.0	31
60	1.2	2.6	26
56	1.0	2.1	22

The ratio of temperature reduction (°F) to weight loss (percent) in these cartons ranged from 10 to 11 degrees for each 1 percent loss in moisture. This ratio is in accord with the calculated amount of cooling obtained by evaporating water.